Excess length of stay due to a central line associated blood stream infections in intensive care units in Argentina, Brazil and Mexico

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Abstract

Objective: To estimate the excess length of stay in an intensive care unit (ICU) due to a central line associated blood stream infection (CLABSI), using a multi-state model that accounts for the timing of infection.

Design: Cohort of 3,560 patients followed for 36,806 days in ICU.

Setting: Eleven ICUs in three Latin American countries, Argentina, Brazil and Mexico.

Patients: All patients admitted to the ICU during a defined time period with a central line place for more than 24 hours.

Results: The average excess length of stay due to a CLABSI increased in ten out of eleven ICUs, and varied between –1.23 days to 4.69 days. A reduction in length of stay in Mexico was probably caused by an increased risk of death due to a CLABSI leading to shorter times to death. Adjusting for patient age and Acute Severity of Illness Score tended to increase the estimated excess length of stays due to CLABSI.

Conclusion: CLABSIs are associated with an excess length of ICU stay. The average excess length of stay varies between ICUs, most likely due to the case-mix of admissions and differences in the ways that hospitals deal with infections.

Introduction

Vascular access poses significant potential risks of iatrogenic complications in general, but in particular, of central line-associated bloodstream infection (CLABSI). Almost 60% of all types of nosocomial bacteremia originate from some form of vascular access.[1] In 2002 we established an international nosocomial infection control consortium (INICC) in Latin America and in other countries of the developing world and found that rates of CLABSI in the ICUs of the hospitals of these countries are 3 to 5 times higher than rates in North American ICUs.[2-13]

Patients with a CLABSI tend to stay longer in the ICU than patients who avoid infection. Numerous estimates of the excess length of stay in hospital due to CLABSI have been reported in the literature and range between 2.7 days[14] and 48.5 days.[15] Forty eight different estimates have been published[16] and these were derived from the following range of methods: making an unadjusted comparison between those with and without infection; matched cohort studies, where patients with an infection are matched to infection-free patients on variables thought to influence length of stay; [17, 18] using the concurrent method, where expert opinion is used to assess excess stay; and, comparing infected with uninfected by statistical analyses, such as multivariable regression where infection is a binary independent variable and length of stay is the continuous dependent variable.[19]

There is a discussion in the literature about biases that arise from the various methods used to find the independent effect of infection on length of stay.[14, 20-22] An important challenge — that is currently under-researched — is to account for the timing of infection.[20, 23] The challenge arises because infection prolongs stay but longer stays increase the chance of infection. This creates a complex dependence between length of stay and infection, and means that standard statistical methods cannot be used. Methods that account for the time-

dependent nature of infection are recognised to be critically important for accurately measuring the excess lengths of stay in hospital due to infection. [23]

The aim of this paper is to apply a statistical method that accounts for the timing of infection, and so will accurately estimate the excess length of stay due to a CLABSI. We used data from eleven intensive care units in Argentina, Brazil and Mexico.

Methods

Data collection

The data were collected as part of the International Nosocomial Infection Control Consortium (INICC).[24] INICC is an international non-profit, multi-center collaborative healthcare-acquired infection control program that employs a surveillance system [2-13] based on the US National Healthcare Safety Network.[25] In this study we look at the CLABSI results from: four ICUs from 2 hospitals in Argentina; [2-3] three ICUs from 1 hospital in Brazil;[9] and four ICUs from 3 hospitals in Mexico.[6]

The laboratory techniques used, training programs for data-collectors, definitions of infection and surveillance activities are described in detail by Rosenthal et al.[24] All patients entering the ICU for more than 24 hours were prospectively followed; detailed information was collected on each day. The following variables were used in this analysis: hospital name and location; date of admission, discharge and death; date, type and site of healthcare acquired infection; central line; Average Severity of Illness Score (ASIS); and age. In this paper we only use data from admissions with a central line, as these are the exposed population, and are the group in whom we want to measure the risks of infection. No other exclusion criteria were applied.

Statistical methods

We used a multi-state approach to model the excess length of stay due to CLABSI. This method has previously been applied to modelling length of stay.[20] A tutorial paper on multi-state and competing risks models is Putter et al.[26] A strength of multi-state models is their ability to incorporate time-dependent exposures. In this study CLABSI is the key time-dependent exposure as it can happen at any time during a patient's stay. The bias of using other methods (such as matching studies) for estimating the effects of time-dependent exposures has been demonstrated.[23] The bias of not accounting for time-dependent exposure depends on the effect of the exposure on length of stay. If the exposure has no effect, the biased analysis will wrongly predict an excess length of stay; if the exposure does extend length of stay, then the biased analysis will overestimate this excess; if the exposure shortens length of stay, the biased analysis will underestimate this reduction.[23]

Figure 1 shows the multi-state model of a patient's day-to-day flow in the intensive care unit. On each day a patient could either die, be infected, be discharged, or stay another day (in which case the process is repeated). Each of these events has a probability, labelled P(Stay, Discharge or Death). One event must occur for each patient on each day, so P(Stay) + P(Discharge) + P(Death) = 1. In the language of state-space models, these probabilities are the *transition rates*, and Death and Discharge are *absorbing states*.[26] To model the effect of a CLABSI we allowed the transition rates to depend on infection status. So we have P(Stay | CLABSI) and P(Stay | no CLABSI), and similarly for the probability of discharge and death. The horizontal line "|", means conditional on.

The proportion of admissions remaining in the ICU by day t, is the survivor function, $S(t)$, familiar to standard survival analysis.[27] In this context the "survivor" function models the

proportion of patients remaining in the ICU and should not be confused with a patient's ultimate survival.

We estimate the survivor function at day *t* by multiplying the probabilities of staying from day 1 up to day *t*. The probability of staying is dependent on whether the patient has a CLABSI or not, so we have the following two survivor functions

$$S(t \mid \text{no CLABSI}) = \text{P}(\text{stay} = 1 \mid \text{no CLABSI}) \ldots \text{P}(\text{stay} = t-1 \mid \text{no CLABSI}).\text{P}(\text{stay} = t \mid \text{no CLABSI})$$
$$S(t \mid \text{CLABSI on day } d) = \text{P}(\text{stay} = 1 \mid \text{no CLABSI}) \ldots \text{P}(\text{stay} = d-1 \mid \text{no CLABSI}).\text{P}(\text{stay} = d \mid \text{CLABSI})$$
$$\ldots \text{P}(\text{stay} = t-1 \mid \text{CLABSI}).\text{P}(\text{stay} = t \mid \text{CLABSI})$$

where *d* is the day the patient was infected, and the above survivor function switches from "no CLABSI" to "CLABSI" on this day. To calculate the excess length of stay due to infection on day *d* we subtract the survivor functions from the day of infection onwards

$$\text{E}(\text{excess LoS} \mid \text{CLABSI on day } d) = \sum_{t=d}^{m} S(t \mid \text{CLABSI on day } d) - S(t \mid \text{no CLABSI}),$$

where E( ) means the expected value. In practice, we do not need to evaluate this sum over every day, but only up to some limit *m*, as for large values of *t* the survivor functions become very small. In this analysis we use a limit of *m* = 60 days. To get the average excess length of stay we multiplied the expected excess length of stay by the probability of CLABSI

$$\text{E}(\text{excess LoS}) = \sum_{d=1}^{m} \text{E}(\text{excess LoS} \mid \text{CLABSI on day } d)\text{P}(\text{CLABSI on day } d). \qquad (1)$$

This equation gives the average excess length of stay for a patient getting a CLABSI at any time during their stay. The probability of CLABSI on day *d* is estimated using the observed distribution of CLABSI times. These stages of estimating the excess length of stay are the same as those used by Beyersmann et al.,[23] although the approaches are different as we estimate survival using a multinomial model, whereas they use Cox proportional hazards.

Software is available to calculate the average excess length of stay, using the method described in Beyersmann et al.[23] in the "etm" library of the R package.[28] An advantage of the method shown here over that described in Beyersmann et al,[23] is that this method is able to adjust for covariates in the estimation of the excess length of stay.[29] So we show results for estimated excess lengths of stay due to CLABSI for a range of patient characteristics. We show the mean excess lengths of stay and 95% credible interval (CI). A 95% credible interval is similar to the familiar 95% confidence interval, but has the simpler interpretation of having a 95% probability of containing the true value.[27]

As well as CLABSIs there are other hospital acquired infections, such as urinary tract infections or ventilator associated pneumonias, which may also prolong a patient's ICU stay. To remove the influence of these other infections we censored admissions with any other hospital acquired infection using the date of the other infection. For example, a patient may have been discharged after 5 days and contracted a urinary tract infection on day 2. Rather than exclude this patient we analysed them as infection free up to day 2. As another example consider a patient discharged after 5 days with a CLABSI on day 2 and urinary tract infection on day 4. Again rather than excluding this patient we analysed them as infection free up to day 2, and then infected from days 2 to 4. Using censoring means that the maximum amount of data on length of stay is used, whilst still only comparing patients with a CLABSI to patients who are infection-free. Those studies that exclude patients with other infections estimate the extra length of stay due to infection compared with patients who had no other infection during their stay. Using censoring we can estimate the extra length of stay due to infection compared with patients who were infection free. If there was a secondary infection that was related to the primary infection then the length of stay was not censored.

Our models were fitted in a Bayesian framework using the JAGS software,[30] using vague priors for all unknown parameters. We used 5,000 Markov chain Monte Carlo samples after a burn-in of 5,000. The convergence of the chains were checked using the "coda" library in R.[31]

For comparison with our multi-state model we fitted a model that ignores the time-dependence of infection. These estimates were made by fitting a generalized linear model, with a dependent variable of days from admission to discharge and independent variable of CLABSI (yes/no).[27] We assumed a Gamma distribution and used a log-link function.

For the descriptive statistics of the study sample, we use the mean and standard deviation for continuous variables that were approximately normally distributed, and the median and inter-quartile range otherwise.

Results

Admissions and central line associated blood stream infections

A total of 3,560 admissions were evaluated: 1,029 from Argentina, 960 from Brazil, and 1,571 from Mexico (Table 1). Four admissions were excluded because it was not recorded whether they died or were discharged. The characteristics of the remaining admissions where a central line was used are shown in Table 1 for the eleven ICUs. There is variability between the ICUs in terms of mean age, ASIS score, death rate and CLABSIs per 1,000 central line days. The rate of CLABSIs per 1,000 central line days ranged from 4.5 to 21.8.

Excess length of stay

The estimated proportions of admissions remaining in the ICU over days since admission are shown in Figure 2 for two of the nine ICUs. The curves show the proportion of patients

remaining in the ICU using the combined data from patients who were discharged or died. Separate curves are shown for infection-free admissions and those with a CLABSI on day 10. We used day 10 to illustrate the divergence in survival curves after infection. Before infection the survival curves for infection-free and infected patients are identical.

In Hospital 1, Medical/surgical ICU, the curve for infection-free patients is below the infected curve, indicating a faster time to discharge or death in these patients. Similar curves were found in most of the other ICUs. However, in Mexico, Hospital 1, Medical/surgical ICU, the survival curve for infected admissions was below the curve for infection-free admissions, indicating a faster time to discharge or death for infected patients.

The estimated excess lengths of stay due to a CLABSI are shown for the eleven ICUs in Table 2. The table shows the estimates from a Gamma model that ignores the time to infection and a multi-state model that accounts for time to infection. In ten of the eleven ICUs the Gamma model gave an estimated extra length of stay that was greater than the multi-state model. The greatest difference was in Brazil, Medical/surgical ICU 3, where the estimated extra length of stay was 5.20 days longer using the gamma model. From here on we only discuss the results of the multi-state model.

The longest excess length of stay was in Argentina, Hospital 1, Coronary ICU, where a CLABSI increased the average length of stay by 4.69 days. The shortest length of excess stay was 0.78 days in Brazil, Medical/surgical ICU 1.

In ten of the eleven ICUs a CLABSI increased the average excess length of stay, and in six ICUs this increase was statistically significant. In Mexico, Hospital 1, Medical/surgical ICU, contracting a CLABSI decreased the length of stay by an average of 1.23 days (although the credible interval of –2.53 to 0.46 days shows that this decrease is not statistically significant).

The shorter average stays of infected admissions in this ICU are also shown in Figure 2, where the curve for infected admissions is below that for non-infected admissions.

In Table 3 we show the excess lengths of stay after adjusting for patient age and ASIS score. By controlling for these other factors, which can have a strong influence on length of stay, we hope to show the independent effect of CLABSI on length of stay. We show the total excess length of stay, from Equation (1), for three levels of ASIS covering admissions at the extremes of illness severity. In general, after adjusting for age and ASIS the excess lengths of stay due to CLABSI are longer. Also, the estimated lengths of stay change greatly depending on ASIS score. In Argentina, Hospital 1, Coronary ICU, the healthiest admissions had the greatest excess length of stay (8.60 days), whereas the sickest admissions had the shortest (3.37 days). In Brazil, Medical/surgical ICU 3, the opposite pattern occurred, with the sickest admissions having the longest excess stay due to infection (13.57 days), and the healthiest the shortest (2.63 days). In Mexico, Hospital 1, Medical/surgical ICU, the sickest admissions had a statistically significantly shorter length of stay of 2.26 days.

It is important to note that the 95% credible intervals for many of these estimates in Table 3 are quite wide, indicating uncertainty in the actual excess length of stay.

Microbial profile of the CLABSIs

The microbial profile of the CLABSIs by country is shown in Table 4. For all 3 countries, the majority of laboratory confirmed CLABSI isolates were Gram-positive (56% to 63%), identified as either Staphylococcus aureus or coagulase-negative staphylococci. 34% to 42% of isolates were attributed to a variety of Gram-negative species. All fungi were identified as Candida.

Discussion

We used a multi-state model that accounted for the time to infection and so avoided the time-dependent bias. When using a gamma model that ignored the time to infection the estimated extra lengths of stay due to infection were greater in 10 of the 11 ICUs (Table 2). This is not surprising as the time-dependent bias leads to an over-estimation of the effects on infection.[32] This highlights the importance of accounting for the time of infection, and indicates that many previous estimates of the excess length of stay due to infection are over-estimates.

The results from the multi-state models showed a pronounced variation in excess length of stay between the different ICUs (Table 2). In Argentina, Hospital 1, Coronary ICU, a CLABSI extended the average length of stay by 4.69 days, whereas in Mexico, Hospital 1, Medical/surgical ICU, a CLABSI reduced length of stay by an average of 1.23 days. This shorter length of stay for infected admissions is, at first, counter-intuitive. Some of the reduced length of stay is due to a shorter time to death, probably because the CLABSI lead to an increased patient morbidity and hence increased risk of death. This argument is supported by the strongest reduction is length of stay in this ICU being in the sickest admissions (–2.26 days, Table 3). So patients who were already quite sick were the most debilitated by a CLABSI and experienced the biggest increased risk of death. Mexico, Hospital 1, Medical/surgical ICU, had the sickest population of the 11 ICUs studied. It also had the highest rate of infection per 1,000 central line days (21.8, Table 1).

After adjusting for age and ASIS the average excess lengths of stay due to a CLABSI tended to increase (Table 3). One exception was Mexico, Hospital 3, where the adjusted lengths of stay were somewhat shorter than the unadjusted estimates (Table 2), although the credible intervals for the adjusted lengths of stay were wide (particularly for ASIS scores 3 and 5). The reduction in length of stay after adjustment may have occurred because infections in this

hospital tended to happen in the oldest or sickest patients (two groups who are both associated with increased lengths of stay).

We attempted to adjust for the potentially important confounders of age and ASIS, but it is possible that we have missed some other important confounders. However, a study of nosocomial pneumonia showed that even adjusting for 13 confounders did not redeem the bias of not accounting for the time of infection.[33] Failing to model an important confounder is unlikely to be as important as failing to model the time of infection.

These findings are valuable to decision makers who wish to predict the change to total costs and health outcomes from reducing risks of infection. Because most of the costs of running a hospital cannot be avoided in the short run[34, 35] they are considered fixed; there will be few cash savings from preventing cases of healthcare acquired infection. Instead bed days will be released and these have a positive economic value as long as demand for acute hospital services exceeds the supply. Understanding the number of bed days released by effective infection control is therefore important when making decisions about adopting additional infection control. Choosing a monetary valuation for these bed days and understanding the health benefits from preventing infection are also important if the complete economic argument for prevention is to be made.[36]

If healthcare services are managed centrally by government and the supply of healthcare is owned by the state, then an appropriate valuation of bed days may emerge from eliciting a willingness to pay from high level decision makers who control the allocation of public sector resources. If healthcare services are de-centralised in a pseudo-market, then the willingness to pay for the marginal bed day could be observed from patients', or their health insurers', behaviour. Neither approach is ideal because of imperfect information about the real costs and benefits of healthcare.[37] A willingness to pay economics approach is however preferred

over using accounting data to estimate costs. Hospital accountants and economists have quite different objectives, treat fixed costs quite differently; and the purpose of collecting these data is to address economics type questions.

Using a good statistical method to estimate additional bed days is crucial, as biased estimates are likely to lead to poor decision making. The estimated excess lengths of stay in this paper are somewhat shorter than similar papers. Our estimates are based on a model that accounts for the time-dependence of infection. Assuming that a CLABSI does increase the average length of stay then previous estimates that ignored the time-dependence would have over-estimated the excess.[23] Our results are some of the most reliable in this area, and indicate that previous analyses may have somewhat over-stated the effect of hospital-acquired infection on length of stay.

We found that the excess length of stay due to a CLABSI varied between ICUs, and also depended on the sickness of the patient. This suggests that it may be difficult to generalise these results to other ICUs, and that the value of preventing a CLABSI would ideally be based on data from that ICU. Prospective surveillance studies are ideal for estimating the extra length of stay due to infection, but new studies should be sure to be adequately powered to detect a possibly small increase in length of stay.[38]

The heterogeneity in the results shown here is mirrored by the heterogeneity in previous estimates in the literature. One important difference is that our results are based on the same statistical method, so the differences must be due to the differences in the case mix of patients, the available resources of the ICU, infection control practices or differences in bacterial strains. In most of the ICUs in this study, a CLABSI extended the overall length of ICU stay (0.78 to 4.69 days, Table 2), leading to increased costs arising from the missed opportunity to deploy bed days to some other productive use. In one ICU a CLABSI reduced

the length of stay, because infection increased the risk of death and so shortened stays for some patients. The small gain in cost for freeing up these bed days would be greatly offset by the loss of life. Good decisions about preventing infection should account for changes to costs and health benefits.[36]

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Table 1: Descriptive statistics by ICU for admissions with a central line

Country	Hospital, ICU	Dates	Admis-sions	Days in ICU	Age (years)	ASIS	Dead	CLABSIs per 1000 central line days	Length of stay (days)
		Statistic	*N*		*mean (SD)*	*mean (SD)*	*n (%)*		*median (IQR)*
Argentina	Hospital 1, Coronary ICU	Mar 99–Mar 02	318	3726	66 (11.6)	3.0 (0.90)	66 (21)	9.9	9 (7–14)
	Hospital 1, Medical/surgical ICU	Mar 99–Apr 02	329	4031	73 (12.8)	3.1 (1.11)	197 (60)	14.4	10 (5–16)
	Hospital 2, Coronary ICU	Jan 01–Apr 02	164	1263	73 (12.6)	3.3 (0.92)	49 (30)	10.9	6 (4–9)
	Hospital 2, Medical/surgical ICU	Jan 01–May 02	218	2609	74 (13.0)	3.3 (0.81)	109 (50)	6.7	8 (5–14)
Brazil*	Medical/surgical ICU 1	Oct 03–Apr 05	273	2243	59 (16.3)	3.7 (1.04)	37 (14)	4.5	6 (3–10)
	Medical/surgical ICU 2	Oct 03–Apr 05	371	5425	53 (19.0)	3.9 (0.72)	101 (27)	6.6	9 (5–20)
	Medical/surgical ICU 3	Oct 03–Apr 05	316	4858	51 (19.2)	3.9 (0.72)	83 (26)	6.6	9 (5–21)
Mexico	Hospital 1, Medical/surgical ICU	Jun 02–Nov 03	341	2926	46 (17.3)	3.8 (0.76)	138 (40)	21.8	7 (4–11)
	Hospital 1, Neurosurgical ICU	Jun 02–Nov 03	309	2884	46 (18.1)	4.1 (0.96)	69 (22)	13.9	6 (4–11)
	Hospital 2, Medical/surgical ICU	Sep 02–Dec 03	673	4989	56 (17.7)	3.5 (1.04)	122 (18)	12.4	5 (3–9)
	Hospital 3, Medical/surgical ICU	Dec 02–Dec 03	248	1852	62 (16.9)	3.6 (0.87)	24 (10)	8.8	6 (4–9)
	Totals	Mar 99–Apr 05	3560	36806					

ASIS = acute severity illness score, CLABSI = central line-associated blood stream infection, ICU = intensive care unit, IQR = inter-quartile range

* All three ICUs in the same hospital

Table 2: Estimated excess length of stay (days) due to a CLABSI using a gamma model and multi-state model

		Gamma model		Multi-state model	
Country	Hospital, ICU	Mean	95% CI	Mean	95% CI
Argentina	Hospital 1, Coronary ICU	6.44	(2.17, 13.51)	4.69	–2.12, 16.28
	Hospital 1, Medical/surgical ICU	5.18	(1.39, 10.88)	3.51	–0.68, 8.92
	Hospital 2, Coronary ICU	4.32	(1.26, 9.98)	2.31	0.61, 3.78
	Hospital 2, Medical/surgical ICU	7.22	(2.40, 16.11)	3.24	–2.76, 14.28
Brazil	Medical/surgical ICU 1	2.32	(–2.45, 14.96)	0.78	–2.47, 7.56
	Medical/surgical ICU 2	7.97	(4.06, 13.64)	4.28	1.64, 7.20
	Medical/surgical ICU 3	8.37	(4.40, 14.14)	3.17	0.65, 6.04
Mexico	Hospital 1, Medical/surgical ICU	2.22	(0.23, 4.88)	–1.23	–2.53, 0.46
	Hospital 1, Neurosurgical ICU	4.92	(2.06, 9.44)	4.06	0.33, 9.30
	Hospital 2, Medical/surgical ICU	4.42	(2.20, 7.79)	3.61	0.19, 9.67
	Hospital 3, Medical/surgical ICU	3.24	(–1.56, 18.87)	3.97	0.23, 8.96

CLABSI = central line associated blood stream infection, CI = credible interval

Table 3: Estimated excess length of stay (days) due to a CLABSI after adjusting for patient age and ASIS score. Estimates are shown for three levels of ASIS and for the mean age (Table 1).

		ASIS = 1		ASIS = 3		ASIS = 5	
Country	Hospital, ICU	Mean	95% CI	Mean	95% CI	Mean	95% CI
Argentina	Hospital 1, Coronary ICU	8.60	–3.93, 21.72	6.45	–1.50, 18.21	3.37	–0.75, 12.32
	Hospital 1, Medical/surgical ICU	6.25	1.02, 11.80	3.54	–0.86, 9.09	1.20	–2.16, 6.45
	Hospital 2, Coronary ICU	3.25	0.91, 5.27	2.58	0.82, 4.09	0.52	0.05, 1.57
	Hospital 2, Medical/surgical ICU	0.00	–0.27, 0.47	0.43	–5.33, 13.36	12.10	2.52, 21.25
Brazil	Medical/surgical ICU 1	1.17	–0.43, 6.04	2.62	–1.31, 11.05	4.33	–3.28, 15.38
	Medical/surgical ICU 2	0.28	–0.12, 1.26	1.42	–0.56, 4.58	3.65	–0.68, 8.43
	Medical/surgical ICU 3	2.63	0.39, 7.40	8.18	2.85, 15.26	13.57	6.05, 20.86
Mexico	Hospital 1, Medical/surgical ICU	–0.01	–0.45, 0.64	–0.52	–1.63, 0.98	–2.26	–4.17, –0.02
	Hospital 1, Neurosurgical ICU	0.07	–0.02, 0.26	0.85	–0.16, 3.21	8.32	2.23, 14.50
	Hospital 2, Medical/surgical ICU	0.30	–0.01, 1.02	2.45	–0.02, 7.47	5.26	–0.41, 14.73
	Hospital 3, Medical/surgical ICU	0.06	–0.13, 1.16	0.47	–1.42, 10.49	0.35	–7.47, 17.78

ASIS = acute severity illness score, CI = credible interval

ASIS = 1, surgical admissions who require routine postoperative observation only; ASIS = 3, admissions who need continuous nursing care and monitoring; ASIS = 5, physiologically unstable admissions who are in a coma or shock and require cardiopulmonary resuscitation or intensive medical and nursing care with frequent reassessment

Estimates from equation (1)

Table 4: Microbial profile of CLABSIs in Argentina, Brazil, and Mexico

Microorganism	**Argentina**	**Brazil**	**Mexico**
Culture Documented CLABSI	32	41	36
Gram-positive bacteria, n (%)	20 (63%)	25 (61%)	20 (56%)
Staphylococcus aureus	12	13	7
Coagulase-negative staphylococci	6	10	12
Enterococci species	2	2	1
Gram-negative bacteria, n (%)	11 (34%)	14 (34%)	15 (42%)
Escherichia coli	3		
Acinetobacter species	1	6	2
Alcaligenes species		1	1
Enterobacter species	2	3	5
Klebsiella species	3	4	2
Proteus species	2		1
Pseudomonas species			2
Serratia species			2
Yeasts, n (%)	1 (3%)	2 (5%)	1 (3%)
Candida species	1	2	1

CLABSI = central line associated blood stream infection

Figure legends

Figure 1: Multi-state model of a patient's day-to-day transitions in an intensive care unit

Figure 2: Estimated proportion remaining in the ICU by days since admission (0 to 30 days) for admissions without a CLABSI (solid lines) and admissions infected on day 10 (dashed lines). Results for two of the nine ICUs.